
Effect of post-harvest handling practices on physico-chemical composition of tomato

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Mhina Erasto Isack and Lyimo Monica (2013) Effect of post-harvest handling practices on physico-chemical composition of tomato. Journal of Agricultural Technology 9(6):1655-1664.

Tomato (*Lycopersicon esculentum* L.) is the world most commercially produced and used vegetable crop. Physiological nature of tomato including high moisture content, high respiration rate, and soft texture make it more vulnerable to post harvest qualitative changes and losses. The objective of this study was to evaluate the effect of post-harvest handling practices on qualitative changes of tomato along the supply chain. The study was carried out in three locations in Arumeru District, Northern Tanzania. Tomato fruit samples were collected randomly at various handling stages; harvesting, transportation and marketing and analysed for physico-chemical composition. The results showed significantly ($p < 0.05$) variations of physico-chemical composition of tomato between varieties subjected to different handling practices. Protein content increased from 16.03-19.09, ash 7.56-8.19, fat 0.89-1.7, reducing sugar 3.40-3.68, carbohydrate 71.07-74.00 g/100 g, total solids 4.99-5.89^oBrix and pH 4.52-4.59 while vitamin C and acidity decreased from 28.43-16.88 mg/100 g and 0.63-0.54 g/100 g respectively from harvesting, transportation to marketing. Fibre and β -carotene were not significantly ($p < 0.05$) affected by the post harvest handling practices. Riogrande variety maintained relatively higher nutritional quality than Onyx variety throughout the supply chain. Poor post harvest handling practices increased qualitative losses of tomato. Proper training of stakeholders along the supply chain on improved harvesting and post-harvest handling techniques could reduce quality losses during harvesting, transportation and marketing of tomato.

Keywords: Tomato, harvesting, post-harvest handling practices, qualitative losses, transportation, marketing

Introduction

Quantitative and qualitative losses occur in tomato crop from harvesting to consumption. Qualitative losses include loss in edibility, nutritional quality, caloric value, and consumer acceptability of the products (Weinberger *et al.*,

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2007). Several interacting factors affect the quality of fresh tomato ranging from pre-harvest, harvest and/or post-harvesting. These factors include crop variety, climate, cultural practices, harvesting techniques, handling, and storage conditions (Majidi *et al.*, 2011). Wilting due to water loss, senescence-associated discolouration (yellowing or browning), mechanical injury, high respiration rate, and decay or rotting are the main causes of quality deterioration of post-harvest loss of tomato (Genova *et al.*, 2006).

Tomato contain a large proportion of water and losses of water is the main cause of weight loss (loss in saleable weight) and wilting where losses of 5-10% of fresh weight can make tomato appear shriveled and lose its quality (Kanlayanarat, 2007); Hossain (2010) reported that, water loss may also induce degradation of nutritional components (e.g. vitamin C loss) and impose stress (water stress) that increases respiration and ethylene production. Ethylene increases product susceptibility to decay.

The chemical composition of tomato fruit depends on factors such as cultivar, maturity, light, temperature, soil, fertilization, irrigation, handling practices, storage, and environmental conditions in which they are grown (Rajkumar *et al.*, 2006; Adubofuor *et al.*, 2010). Rattanaporn *et al.* (2005) observed slight changes in chemical composition of protein during five months of storage but the protein content of tomato was influenced by variety, handling practices, climate, location and growing season. Mutari and Debbie (2011) observed that the ash contents of tomato varied with handling stages and reduction of moisture content lead to increased dry matter. Variety and dry matter content of tomato determines its ash content and is inversely proportion to the amount of moisture present in it. Like protein, tomato is also a poor source of fat, as it contains a very low amount of fat which is important for resisting injuries from mechanical damages and enzymic browning (Owori and Agona, 2003).

Babitha and Kiranmayi (2010) reported that carbohydrate contents (mainly the amounts of glucose and fructose) increases progressively through maturation and ripening of tomato and can account for 50% of the dry matter. Total soluble solids (°Brix) are one of physical chemical parameters used as an index of tomato ripening. This parameter tends to increase as the ripening proceeds and vary between varieties (Sammi and Masud, 2007). Kays (1997) reported that changes of total soluble solids content was a natural phenomenon occurring during ripening and was correlated with hydrolytic changes of starch concentration during ripening in post harvest period.

Post-harvest handling practices are of great importance in preventing qualitative and quantitative losses of tomato which have shown to be high in most tomato growing areas world wide, yet very few studies have been carried

out to establish the nature, types and magnitude of the losses. Qualitative changes due to improper handling of tomato along the supply chain can cause partial or total loss of fresh produce. The objective of this study was to evaluate the effect of post-harvest handling practices on qualitative changes of tomato along the supply chain.

Materials and methods

Two varieties (Onyx and Riogrande) of fresh tomato samples commonly cultivated by farmers in Arumeru district, Arusha, Tanzania were randomly collected at three handling stages; immediately after harvesting, transportation, (immediately after reaching the market) and marketing (during the selling period). At each stage 10 tomato fruits of each variety (making a total of 60 samples) were collected and preserved in cool boxes (4°C) and transported to the Government Chemist Laboratory Agency, Dar es Salaam for analysis.

Sample preparation

The tomato samples (10) of each variety from each handling stage were weighed and rinsed with de-ionized distilled water followed by gentle blotting with a paper towel. Using a kitchen knife each fruit was quartered through the polar diameter and two alternate quarters were used for a composite sample. The samples were then homogenised using a warring blender. The homogenous mixture was analysed at once in duplicate for proximate composition, mineral content (calcium, magnesium and potassium), carotenoids (β -carotene and lycopene), Vitamin C, reducing sugars, total solids, titratable acidity and pH.

Analyses

Proximate composition was determined in duplicate according to the Association of Official Analytical Chemists (AOAC 1995) methods. The moisture content in fresh tomato samples was determined by drying using an air oven (WTC) Binder, type E115 RWF 12/5) at 105°C for three hours (method 920.151) using sample of 10 g fresh tomato instead of 5 g dried sample. Crude protein content was determined using micro-Kjeldahl (%protein = % N x 6.25) (method 920.87). Crude fat content by ether extraction using the Soxhlet system, (method 960.39). Crude fibre content by using dilute acid and alkali (method 920.86). Ash content by using muffle furnace (method 923). Carbohydrate content was calculated as percent difference (% carbohydrate = 100 – (% Protein + % Crude fibre +% Crude fat +% Ash content).

The amount of calcium, magnesium and potassium in tomato samples were determined induplicate by atomic absorption spectrophotometer method described in official methods (AOAC, 1995), (method 968.08).

Total Carotenoid content was determined by extraction method using acetone as described Rodriguez-Amaya and Kimura (2004).

Lycopene content was determined according to the method described by Rodriguez-Amaya and Kimura (2004). Vitamin C content was determined by 2, 6-dichloroindophenol Na derivative as described in official methods (AOAC, 2000) (method 967.21). The total soluble solids (^oBrix) were analyzed by the using refractive index as outlined in official methods (AOAC, 1995) (method 970.59). Reducing sugars were determined by Luff-Schoorl method as described by Egan *et al.* (1981). Total acidity (expressed as citric acid %) was analyzed by the use of titmetry method as outlined in AOAC (1995) (method 942.15). The pH of the tomato samples was determined by the use of pH meter as outlined in AOAC (1995) (method 981.12).

Data from laboratory analyses was analyzed by GenStat Statistical Package Version 13.3 Computer software. Differences for mean nutrient contents at different handling stages were separated using Duncan's multiple range tests at $P < 0.05$.

Results and discussions

Effect of varieties on physico-chemical composition of tomato

The results showed significant changes ($p < 0.05$) in nutrient content between varieties (Onyx and Riogrande) except for crude-fibre, vitamin C and β -carotene (Table 1). Variation in nutrient content between varieties could be attributed by genotypic differences modified by environmental effect where tomatoes were grown. Variations in nutrient content in different varieties of tomatoes have been reported earlier by Gupta *et al.* (2011). The results of the present study have shown that tomatoes are low in fat content as reported earlier by Rwezaula *et al.* (2005) who observed that tomatoes are deficient in fats that make them to be among the healthiest vegetable good for human health (weight reducing diet). The crude fiber content of the tomato varieties was observed to be higher in Riogrande than in Onyx (Table 1). Similar trend in fibre content (0.5-0.7 g/100 g) in four varieties of tomato have been reported by Shibli *et al.* (1995). Dietary fiber is very important in lowering body cholesterol level consequently decreasing the risk of cardiovascular diseases. Of the two varieties analyzed, Onyx had the highest carbohydrate content than Riogrande suggesting higher energy values hence, a good variety for fresh consumption.

Likewise, Onyx having higher reducing sugar content suggests having better taste than Riogrande when consumed fresh.

Table 1. Effect of varieties on physico-chemical composition of tomato

Variety	g/100 g								mg/100 g					°Brix	
	Ash	P	F	FB	CH	TA	R.S	Vit C	β-car	Lycop	Ca	Mg	K	TSS	pH
Onyx	7.56	16.0	1.	0.	74.0	0.51	3.68	22.30	0.03	5.35	45.60	5.30	50.6	4.99	4.59
Riog	8.19	19.0	0.	0.	71.0	0.64	3.40	23.80	0.02	2.72	48.20	6.20	56.4	5.89	4.52
CV%	1.70	9.90	0.	13	2.40	2.30	5.20	5.50	11.8	0.60	2.30	2.30	2.60	1.10	0.70
LSD _{0.05}	0.19	2.45	0.	0.	2.45	0.02	0.28	1.79	4.05	0.04	1.55	0.19	0.002	0.08	0.05
S.E (±)	0.14	1.74	0.	0.	1.73	0.01	0.20	1.27	2.87	0.03	1.10	0.13	1.42	0.06	0.03

P=Protein, F= Fat, FB=Fibre, CHO=Carbohydrates, TA=Titrate acidity, R.S=Reducing Sugars, Vit C= Vitamin C, β-car= β-carotene, Lycop= Lycopene, Ca= Calcium, Mg= Magnesium, K= Potassium, TSS=Total soluble solids, Riog=Riogrande, LSD= Least Significant Difference, S.E= Standard Error, CV= Coefficient of Variation

The study has shown that Riogrande had higher amount of titratable acidity than Onyx suggesting its stability for processing as it may halt proliferation of spoilage micro-organisms likely to attack different tomato processed products. Higher total soluble solid content observed in Riogrande also suggests its suitability as raw material in tomato paste processing industries. Higher soluble solid content in tomatoes are desirable characteristic for the canned tomato industries as they reduce the cost of processing hence improve the quality of the processed products (Turhan and Seniz, 2009). The values for total soluble solids (°Brix) observed in the present study are within the range reported by other workers (Naz *et al.*, 2011, Gupta *et al.*, 2011) who observed values of 4.9-5.5 and of 5.1-5.5°Brix respectively in six varieties of tomato. Also variations in pH (4.52-4.59) observed in the present study compare well with the findings reported by Babitha and Kiramanyi (2010) who observed pH range of 4.0-4.5 in different varieties of tomato.

Effect of handling practices on physico-chemical composition of tomato

There was a significant variation ($p < 0.05$) between nutrient content and handling practices along the supply chain except for crude-fibre and carotene (Table 2). Differences in nutrient content observed in the present study might be attributed by handling practices, magnitude of ripening, metabolic changes, environmental conditions, and storage conditions at different stages. The observed increase in ash content of tomatoes along the supply chain (Table 2)

could be associated with the gradual reduction of moisture content (increasing in dry matter) attributed by exposure of tomato to sunlight and high temperature during transportation and marketing stages. Tomatoes were packaged in wooden crates, stacked on top of each prior being loaded into trucks and transported to the markets. This practice might have increased the internal temperature of the produce. Perez *et al.* (2003) and Mutari and Debbie (2011) observed water losses in tomato depended on temperature and relative humidity conditions of the storage/handling environment which also induced changes of nutritional components in tomato by imposing stress (i.e. water stress) that increases its dry matter content including ash.

There was a significant ($p < 0.05$) increase in carbohydrate content in tomato fruits at the three stages along the supply chain (Table 2). It has been observed that among the changes that may occur during ripening of tomatoes, is the change in the carbohydrate composition mainly due to substrate utilization and action of hydrolytic enzymes that resulted to a decrease in starch and an increase in sugar content (Workneh and Osthoff, 2010). Increase in reducing sugar content of tomato at different stages of handling observed in this could be attributed by increased ripening with time as well as high storage temperature at which tomato were subjected during marketing period. Shahnawz *et al.* (2012) and Tadesse *et al.* (2012) reported that an increase in reducing sugar content of tomato could be due to the breakdown of polysaccharides into water soluble sugar in glycolysis process during storage.

Significant decrease ($p < 0.05$) in acidity content of tomatoes along the supply chain observed in this study might be attributed to utilization of citric acid by micro-organisms as a carbon source and the disappearance of citric acid during ripening process. Sammi and Masud (2007) observed that during ripening of tomatoes, malic acid disappears first, followed by citric acid (which results in reduction of amount of titratable acidity), suggesting the catabolism of citrate via malate. Whereas Bhattacharya (2004) reported that acidity is often used as an indication of maturity as acid decreases during ripening of fruit. The observations which also explain the variation of pH along the supply chain (Table 2).

Vitamin C is necessary for normal metabolism, wound healing and collagen synthesis. The results of the present study revealed significant ($p < 0.05$) decrease in vitamin C content in tomatoes from harvesting to marketing stages (Table 2). Different environmental conditions, exposure of tomato samples to air, sunlight and temperatures along the supply chain coupled with high solubility of ascorbic acid in water and the relative ease with which it is oxidized makes this vitamin particularly susceptible to storage and handling conditions. Workneh and Osthoff (2010) reported that higher storage

temperatures are known to have an increasing effect on the rate of decrease in ascorbic acid content in tomatoes during storage and the decrease occurs rapidly after full ripening stage. On other hand significant ($p < 0.05$) increase in lycopene content of tomatoes from harvesting to marketing stages in the present study might be due to exposure of tomatoes to high temperature and light during transportation and marketing. Brandt *et al.* (2006) reported that lycopene formation in tomato is influenced by light and temperature, the optimum temperature being 25-30°C above which carotene is favoured.

Combination of varieties and post-harvesting practices on physico-chemical composition of tomato

The results showed that, there was significant ($p < 0.05$) variation in nutrient content between Onyx and Riogrande except reducing sugars, total soluble solids and pH along the supply chain (Table 3). Vitamin C content was most susceptible to post-harvest handling practices as significant ($p < 0.05$) decrease was observed along the supply chain (Table 3). Workneh and Osthoff (2010) and Sohail *et al.* (2011) observed that due to its high solubility in water and the relative ease with which it is oxidized, vitamin C is relatively unstable to environmental conditions (air, light, temperatures and heat) that makes it susceptible to storage and handling conditions which could also explain the results obtained in this study.

Higher changes of nutrient content of tomato were observed at marketing stage (Table 3). This could be due to the fact that tomato is a climacteric fruit that continues to respire even after harvesting. Since dry matter content continues to accumulate with ripening stages supporting the conclusion of Babitha and Kiranmayi, (2009), it is expected that tomato harvested at mature green stage upon reaching the marketing stage will ripen and hence acquiring higher nutrient composition.

Conclusion

The study revealed higher quality changes of nutrient composition of tomato at marketing stage compared to harvesting and transportation stages. Most of the analyzed nutrients showed relative susceptibility to post-harvest handling practices with vitamin C being the most susceptible while fibre and β -carotene was the most stable. Losses were mainly attributed by poor handling practices exhibited stakeholders along the supply chain, hence, in view of these; proper training of stakeholders within tomato supply chain on improved harvesting and post-harvest handling techniques could reduce quality losses likely to occur at farm level, during transportation and marketing of tomato.

Acknowledgement

The authors wish to thank the Ministry of Agriculture Food Security and Cooperatives (MAFSC) for providing funds to undertake the study and the Department of Food Science and Technology at Sokoine University of Agriculture (SUA), Morogoro-Tanzania for technical support The Chief Government Chemists Laboratory Agency for analysis of the specimens.

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(Received 23 May 2013; accepted 31 October 2013)

Table 2. Effects of handling practices on physico-chemical composition of tomato at harvesting, transportation and marketing

HP ¹	g/100 g							mg/100 g						Brix	
	Ash	CP	CF	CFB	CHO	R.S	TA	Vit C	β-car	Lycp	Ca	Mg	K	TSS	pH
Harvest	7.40 ^{ab}	15.01 ^{a b}	1.18 ^{a b}	0.71 ^{a a}	70.27 ^{a a}	3.05 ^{aa}	0.63 ^{c c}	28.43 ^c	0.02 ^a	3.43 ^a	44.21 ^a	5.29 ^a	51.10 ^a	4.99 ^a	4.49 ^a
Transit	7.84 ^{b a}	18.49 ^{ba}	1.35 ^{b b}	0.72 ^{a a}	71.81 ^{a b}	3.97 ^{b b}	0.56 ^{b b}	23.90 ^b	0.03 ^a	3.86 ^b	46.31 ^b	5.66 ^b	52.57 ^a	4.99 ^a	4.52 ^a
Market	8.39 ^{c c}	19.18 ^{bb}	1.35 ^{ba}	0.77 ^{a a}	75.53 ^{ba}	4.50 ^{c c}	0.54 ^{a a}	16.88 ^a	0.03 ^a	4.80 ^c	50.05 ^c	6.28 ^c	56.78 ^b	6.35 ^b	4.67 ^b
CV%	1.70	9.90	0.70	13.30	2.40	5.20	2.30	5.50	11.80	0.60	2.30	2.30	2.60	1.10	0.70
S.E (±)	0.19	1.74	0.01	0.09	1.734	0.19	0.01	1.27	2.87	0.03	1.10	0.13	1.42	0.06	0.03

Means within the same column superscripted by the same letter are not significantly different at P< 0.05 following Duncan's Multiple Range Test (DMRT). CP=Crude protein, CF= Crude fat, CFB=Crude fibre, CHO=Carbohydrates, R.S=Reducing Sugars, TA=Titrate acidity, Vit C= Vitamin C, β-car= β-carotene, Lycp= Lycopene, Ca= Calcium, Mg= Magnesium, K= Potassium, TSS=Total soluble solids, pH= Hydrogen potential, S.E= Standard Error, CV= Coefficient of Variation; HP¹= handling practices

Table 3. Combination of varieties and post-harvesting practices on physico-chemical composition of tomato (Values with significant changes)

PP	Variety	g/100 g					mg/100 g				°Brix	
		Ash	Fat	R.S	Acidity	Vit C	Lycopene	Mg	K	TSS	pH	
1	Onyx	6.52	1.24	3.05	0.54	23.25	4.66	4.50	43.55	4.99	4.48	
	Riog	8.28	1.13	3.05	0.72	33.60	2.21	6.08	58.65	4.99	4.50	
2	Onyx	7.71	1.59	3.94	0.50	23.22	5.23	5.18	46.83	4.99	4.52	
	Riog	7.97	1.11	3.99	0.62	23.89	2.50	6.13	58.32	5.00	4.52	
3	Onyx	8.45	2.26	4.05	0.49	19.80	6.16	6.17	61.40	7.70	4.78	
	Riog	8.33	0.44	4.95	0.59	13.96	3.45	6.40	52.15	5.00	4.55	
CV%		1.7	0.7	5.2	2.3	5.50	0.6	2.3	2.6	1.1	0.7	
LSD _{0.05}		0.33	0.02	0.49	0.03	3.11	0.06	0.32	3.47	0.14	0.08	
S.E (±)		0.13	0.01	0.19	0.01	1.27	0.03	0.13	1.42	0.06	0.03	

R.S=Reducing Sugars, TSS=Total soluble solids, Vit C= Vitamin C, Mg= Magnesium, K= Potassium, pH= Hydrogen potential, S.E= Standard Error, CV= Coefficient of Variation, 1=Harvesting, 2=Transportation, 3=Marketing, Riog=Riogrande; PP= Post-harvest practi.

